Proceedings of the 8th World Congress on Civil, Structural, and Environmental Engineering (CSEE'23)
Lisbon, Portugal – March 29 – 31, 2023
Paper No. ICEPTP 191
DOI: 10.11159/iceptp23.191

Phytoremediation of Cadmium and Nickel Contaminated Clay Soil in Lebanon Using Poplar Trees

Alice Abou Chacra[1], Samir Mustapha[2], Darine Salam[3], Walid El Kayal[4]
[1]Baha and Walid Bassatne Department of Chemical Engineering and Advanced Energy, American University of Beirut, Beirut, Lebanon
[2]Department of Mechanical Engineering, American University of Beirut, Beirut, Lebanon
[3]Department of Civil and Environmental Engineering, American University of Beirut, Beirut, Lebanon
[4]Department of Agriculture, American University of Beirut, Beirut, Lebanon
ata25@mail.aub.edu; sm154@aub.edu.lb; ds40@aub.edu.lb; we21@aub.edu.lb

Abstract **-** Pollution has been on the rise ever since the industrial revolution. In Lebanon, water and air pollution are among the most serious issues that require immediate solutions. Further, soil pollution cannot be excluded since it affects water sources and human nutrition. Soil pollution can happen due to hydrocarbon contamination or inorganic contamination like metal presence. More specifically, there are heavy metals (HMs) that if present above certain concentrations become contaminants to soils and crops. In this work, the use of plants, precisely a hyperaccumulator seedling called poplar, was explored as a remediation technique for cadmium (Cd) and nickel (Ni) contamination in soil. A pot experiment is set up in a greenhouse compartment at the American University of Beirut using synthetically contaminated clay soil to evaluate the efficiency of poplar seedlings in phytoremediation during a period of four months. The use of hyperspectral imaging (HSI) to detect and quantify heavy metals absorbed by different parts of the plants is also being assessed. The results showed that cadmium mostly accumulates in poplar leaves while nickel is found mostly in the roots of the plant, according to the collected data until the present time.

Keywords**:** Soil Pollution and Treatment, Phytoremediation, Heavy Metals, Poplar Trees, Hyperspectral Imaging

1. Introduction

There are certain levels of heavy metals presence in the soil beyond which they become contaminants. The main source of heavy metal contamination in soil is anthropogenic activities like the disposal of metal and industrial wastes and the leakage of petrochemicals. Most commonly found heavy metals at sites include lead, arsenic, cadmium, chromium, copper, zinc, nickel, and mercury [1]. Nevertheless, what truly counts as a contamination for plants is the bioavailable part of these metals in the soil. Some of the impacts of the presence of such metals in the soil and plants include human health risks such as cancer as well as a decrease in land usability. There are three main methods for the removal of heavy metal contaminants from soil using what is known to be the best demonstrated available techniques (BDATs) which include immobilization techniques, soil washing, and phytoremediation. In this work, the focus will be on phytoremediation which involves using vegetation to remove, contain, or render the contaminants harmless [2]. The metals of interest are cadmium (Cd) and nickel (Ni) since they are present in the Lebanese soils above the maximum total metals' permissible limits according to WHO [3]. To remove these metals using phytoremediation, a plant should exhibit a high bioaccumulation coefficient, fast growth, and deep roots [4]. Poplar trees are short-rotation trees that have been widely used as hyperaccumulator trees previously because they have these characteristics. Hence, they were put to test in a designed pot experiment to remove cadmium and nickel from synthetically contaminated soil. The main two objectives of this study are to evaluate poplar trees' potential for removing cadmium and nickel from the soil as well as to assess the use of hyperspectral imaging in detecting and quantifying accumulated heavy metals in the plants' tissues through benchmarking the results to measured HMs levels using atomic absorption spectrophotometry (AAS). The novelty of this work lies in applying phytoremediation in Lebanon using poplar trees and evaluating the potential use of HSI in detecting levels of HMs in plants' tissue.

2. Methodology

Eighteen pots were used for the experiment; 6 for soil contaminated with 7 mg cadmium/kg of dry soil, 6 for soil contaminated with 100 mg nickel/kg of dry soil, and 6 for control pots with no added contamination (i.e., three treatments). The choice of contamination levels was based on the reviewed contamination levels present in Lebanon's soil. The soil used for the experiments was collected from a Lebanese region called Bekaa, known for its agricultural activities [5]. The soil analysis was done to find the soil particle size distribution (clay soil), moisture content (7.18%), organic matter content (2.95%), pH (6.62) and conductivity (486 μS/cm), total calcium carbonate (31.86%), available sodium (39.6 mg/kg), potassium (178 mg/kg), and phosphorus (67.51 mg/kg), background total cadmium (5.234 mg/kg), background total nickel (98.18 mg/kg), bioavailable cadmium (0.2335 mg/kg), and bioavailable nickel (3.259 mg/kg). Initially, three plants were analysed upon receive to determine the background levels of Cd and Ni in the different parts of the plants. For the pot experiments, at two- and four-month intervals, a total of 9 pots were analysed for the cadmium and nickel content, 3 of each of the pre-mentioned treatments. The plants were divided into roots, twigs (or stems), and leaves to have a better understanding of the metal uptake. The collected crop parts were rinsed with distilled water as shown in Figure 1, dried in the oven before grinding, and finally ashed in a furnace at 600°C for two hours. Then, the ash was digested with diluted hydrochloric acid and the digestate was analysed for Cd and Ni using atomic absorption spectrophotometry.

Figure 1: Rinsed Plant Parts

3. Results and Discussion

The results of the plant analysis over the whole interval are presented in Table 1. In the case of pots with added Cd or Ni contamination, the plants showed an overall increase in HMs concentration over time. In cadmium trees (i.e., trees planted in soil with added Cd contamination), the highest metal content was measured in the leaves. In Ni contaminated pots, the metal was mostly concentrated in the roots of poplar trees. Those results are in line with results reported in literature. Robinson et al. [6], reported root cadmium concentrations 0.9 times higher than the metal concentration in the shoots of poplar. Furthermore, Kacalkova et al. [7] found that nickel concentrations were the highest in the poplar's roots. Besides, the observation of contamination not showing in the poplar seedlings' parts in a particular order at each temporal point of analysis was reported in literature [7] [8].

Moreover, hyperspectral scans using HySpex camera with 288 spectral bands in a 950-2500 nm spectral range were taken for dried tree stems of plants analysed for background contamination, after two months, and after four months of the experiment. As seen in Figure 2, the reflectance differs with an introduction of contamination to the plants. The correlation between these scans and atomic absorption spectrophotometry results is yet to be found. Nevertheless, it is expected that spectral reflectance of the plant will be positively correlated with the increase of cadmium and nickel content, as seen in a study about phytoremediation of copper using a small hyperaccumulator tree called Jatropha curcas [9].

Table 1: Analysis of Plants using AAS After Two- and Four-month Intervals

		Metals	**Roots**	**Stem**	**Leaves**
Initial	Control trees	Cd (mg/kg)	0.066 ± 0.058	0.144 ± 0.037	0.294 ± 0.122
		Ni (mg/kg)	4.107 ± 1.102	1.871 ± 1.476	3.438 ± 1.411
After 2 months	Control trees	Cd (mg/kg)	0.068 ± 0.009	0.047 ± 0.013	0.045 ± 0.012
		Ni (mg/kg)	14.579 ± 9.193	1.958 ± 1.083	2.600 ± 1.300
	Cadmium trees	Cd (mg/kg)	0.193 ± 0.084	0.191 ± 0.020	0.309 ± 0.019
	Nickel trees	Ni (mg/kg)	49.219 ± 16.343	5.699 ± 0.608	11.660 ± 4.160
After 4 months	Control trees	Cd (mg/kg)	0.024 ± 0.005	0.025 ± 0.004	0.046 ± 0.023
		Ni (mg/kg)	15.091 ± 2.683	3.272 ± 0.808	3.560 ± 2.129
	Cadmium trees	Cd (mg/kg)	0.158 ± 0.121	0.085 ± 0.078	0.583 ± 0.227
	Nickel trees	Ni (mg/kg)	161.535 ± 45.032	12.966 ± 7.356	39.562 ± 9.160

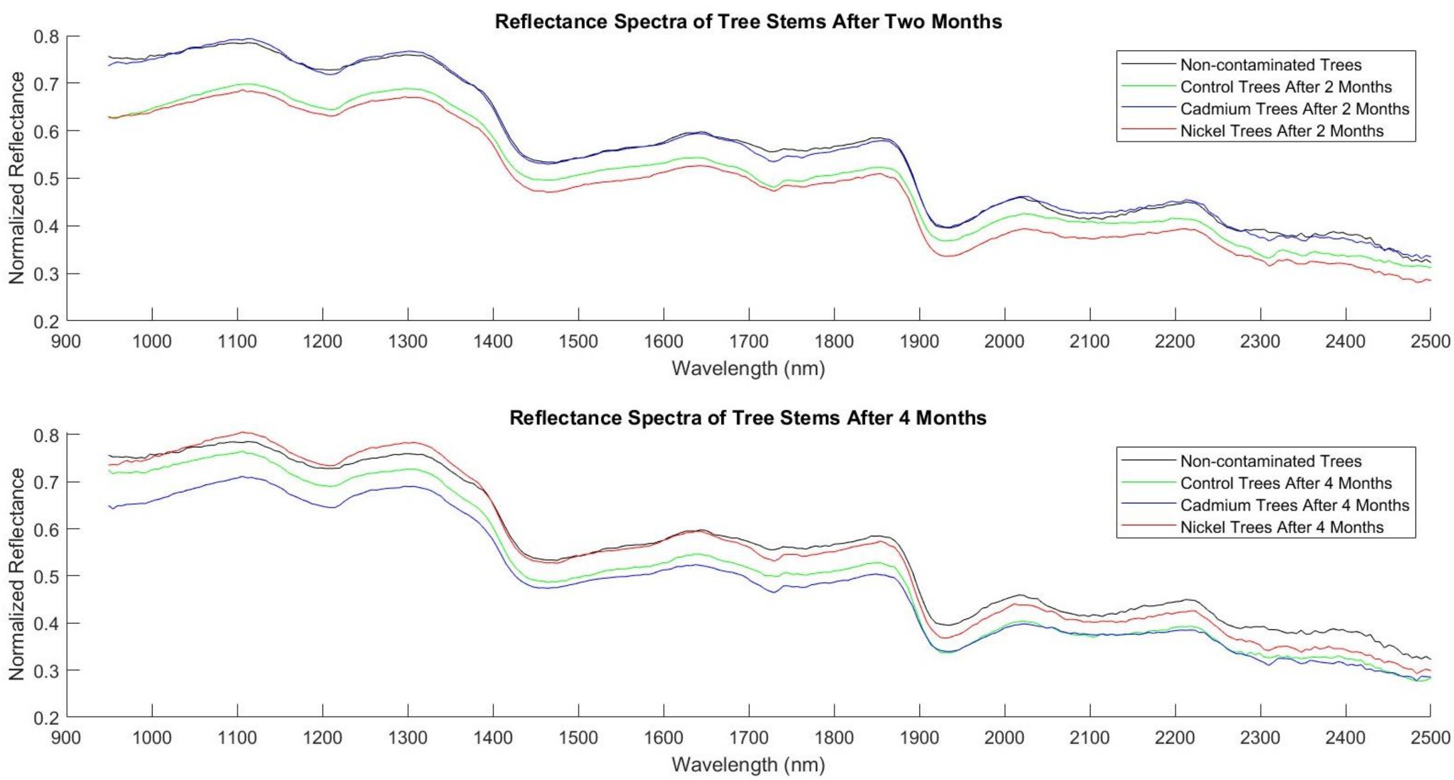

Figure 2: Hyperspectral Images of Tree Stems After Two and Four Months

4. Conclusion

Poplar trees can be used for the phytoremediation of soil in Lebanon which has cadmium and nickel concentrations above permissible limits according to the literature review. So far, it has been observed that cadmium accumulate mostly in leaves while nickel in roots, where in both cases the metal content increases in these parts throughout the experiment. Hyperspectral imaging will be the most interesting part of this work since it provides the ability to predict the contamination in plant tissues in the future without the need to terminate the plant based on the collected database measured using atomic absorption spectrophotometry.

Acknowledgments

The authors would like to acknowledge the financial support from the Middle East Partnership Initiative – Tomorrow's Leadership Graduate program at the American University of Beirut provided to Ms. Alice Abou Chacra with the following award number SNEAAC19CA0037.

References

[1] R. A. Wuana and F. E. Okieimen, "Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation," *ISRN Ecol.*, vol. 2011, p. e402647, Oct. 2011, doi: 10.5402/2011/402647.

[2] T. McIntyre, "Phytoremediation of Heavy Metals from Soils," in *Phytoremediation*, D. T. Tsao, Ed. Berlin, Heidelberg: Springer, 2003, pp. 97–123. doi: 10.1007/3-540-45991-X_4.

[3] T. M. Chiroma, R. O. Ebewele, and F. Hymore, "Comparative assessment of heavy metal levels in soil, vegetables and urban grey water used for irrigation in Yola and Kano," *Int. Refereed J. Eng. Sci. IRJES*, vol. 3, pp. 1–9, Jan. 2014.

[4] A. M. Paz-Alberto and G. C. Sigua, "Phytoremediation: A Green Technology to Remove Environmental Pollutants," *Am. J. Clim. Change*, vol. 02, no. 01, Art. no. 01, 2013, doi: 10.4236/ajcc.2013.21008.

[5] T. Darwish, I. Jomaa, M. Awad, and R. Boumetri, "Preliminary contamination hazard assessment of land resources in Central Beka plain of Lebanon," *Leban. Sci. J.*, vol. 9, Jan. 2008.

[6] B. H. Robinson, T. M. Mills, D. Petit, L. E. Fung, S. R. Green, and B. E. Clothier, "Natural and induced cadmium-accumulation in poplar and willow: Implications for phytoremediation," *Plant Soil*, vol. 227, no. 1, pp. 301–306, Dec. 2000, doi: 10.1023/A:1026515007319.

[7] L. Kacalkova, P. Tlustoš, and J. Száková, "Chromium, Nickel, Cadmium, and Lead Accumulation in Maize, Sunflower, Willow, and Poplar," *Pol. J. Environ. Stud.*, vol. 23, pp. 753–761, Jan. 2014.

[8] M. Rafati, N. Khorasani, F. Moattar, A. Shirvany, F. Moraghebi, and S. Hosseinzadeh, "Phytoremediation Potential of Populus Alba and Morus alba for Cadmium, Chromuim and Nickel Absorption from Polluted Soil," *Int. J. Environ. Res.*, vol. 5, no. 4, pp. 961–970, Sep. 2011, doi: 10.22059/ijer.2011.453.

[9] J. F. García-Martín, A. T. Badaró, D. F. Barbin, and P. Álvarez-Mateos, "Identification of Copper in Stems and Roots of Jatropha curcas L. by Hyperspectral Imaging," *Processes*, vol. 8, no. 7, Art. no. 7, Jul. 2020, doi: 10.3390/pr8070823.